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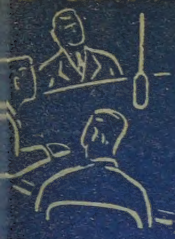

Round Table

INDUSTRIAL USES OF ATOMIC ENERGY IN THE NEXT TEN YEARS

An NBC Radio Discussion by ARTHUR HOLLY COMPTON WILLIAM DAVIDSON, ENRICO FERMI, CHARLES H. GREENEWALT, MURRAY JOSLIN, DONALD LOUGHRIDGE, CHARLES ALLEN THOMAS W. ALLEN WALLIS *and* WALTER H. ZINN

on the occasion of
The Tenth Anniversary of the Opening of the Atomic Age

Including

THE PROSPECTS FOR INDUSTRY

By EDWIN J. PUTZELL, JR.
Secretary, Monsanto Chemical Company

POLICY PROBLEMS IN THE DEVELOPMENT OF CIVILIAN NUCLEAR POWER

By EUGENE M. ZUCKERT
Member, U.S. Atomic Energy Commission

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WILLIAM DAVIDSON, director, Office of Industrial Development, Atomic Energy Commission

ENRICO FERMI, distinguished service professor of physics, University of Chicago; designer and builder of the first atomic pile; professor of theoretical physics, University of Rome (1927–38); professor of physics, Columbia University (1939–41); research work on atomic energy and atomic bomb (1942–45); awarded Nobel Prize for physics, 1938

CHARLES H. GREENEWALT, president, E. I. duPont de Nemours and Company since 1948; with the DuPont Company since 1922, formerly serving with the chemical department, the explosives department, the development department, the pigments department, and as vice-president

MURRAY JOSLIN, assistant to the president, Commonwealth Edison Company

DONALD LOUGHRIDGE, assistant director of Reactor Development, Atomic Energy Commission

CHARLES ALLEN THOMAS, president, Monsanto Chemical Company; member of the Manhattan Project in charge of the Clinton Laboratories at Oak Ridge during the war; formerly president of Thomas and Hochwalt Laboratories (1926–36); deputy chief National Defense Research Committee (1942–43)

W. ALLEN WALLIS, professor and chairman of the Committee on Statistics, University of Chicago

WALTER H. ZINN, professor of physics, University of Chicago; director of Argonne National Laboratory; research work on atomic energy and atomic bomb (1942–45)

THE PROSPECTS FOR INDUSTRY. *By* EDWIN J. PUTZELL, JR. 1

POLICY PROBLEMS IN THE DEVELOPMENT OF CIVILIAN NUCLEAR POWER
By EUGENE M. ZUCKERT 1

978th Broadcast in Cooperation with the National Broadcasting Company

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Industrial Uses of Atomic Energy in the Next Ten Years

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This ROUND TABLE *program is part of the celebration of the tenth anniversary of the opening of the atomic age. Ten years ago, on December 2, 1942, on the campus of the University of Chicago, the first self-sustaining nuclear reaction occurred, marking man's first controlled release of atomic energy. As part of the anniversary ceremonies, the University of Chicago and the Chicago Association of Commerce and Industry jointly sponsored a panel discussion of "Industrial Uses of Atomic Energy in the Next Ten Years" before a large group of business and industrial leaders. Taking part in this panel were several of the distinguished scientists who were present at the time of the first chain reaction (Mr. Compton, director of research for the wartime project; Mr. Fermi, designer and builder of the first atomic pile; Mr. Greenewalt; Mr. Zinn), leaders of industry now working on the industrial uses of atomic energy, and two representatives from the Atomic Energy Commission. The following* ROUND TABLE *presents part of this panel discussion which took place on this anniversary occasion.*

MR. GREENEWALT: Power from atomic energy, entirely for itself, is not economic in the light of today's knowledge. However, Mr. Joslin and Mr. Loughridge both appear to believe that the military developments (Mr. Loughridge) and a dual-purpose plant which makes plutonium along with power (Mr. Joslin) would help the development of the power per se, alone, by virtue of what is learned in connection with the construction of those plants. That, I take it, is the point of view with which you both would agree.

We have had nothing but sweetness and light so far. Is there anyone who disagrees with that point of view?

MR. FERMI: There is one point on which I merely seek information. Power, I suppose, has a different cost in different locations. Near a coal

mine presumably power is cheap. Near a place where hydroelectric power can practically be developed it is cheap. There are places—perhaps not so much in this country as in other parts of the world—where conditions may not be so favorable. I wonder whether anybody has the facts to discuss this point of view. I would be personally curious to know whether the argument that power cannot compete without also commanding in the same plant the price of the plutonium produced potentially as a weapon would apply geographically to all the world, to most of the world, to the United States, or to where?

MR. GREENEWALT: Is there anyone who wishes to deal with that question? Is there any knowledge on that question? Davidson, have your people given consideration to that problem?

MR. DAVIDSON: The Commission has given quite a bit of consideration to that. In fact, today it has a team looking into the high-cost areas in this country. This team is a part of the Reactor Development Division, so I think that Loughridge can probably tell us what the status is, if it is available for publication at the moment.

MR. LOUGHRIDGE: It is in a study status so that the final conclusions are not available as yet. But I can say this: That in the preliminary survey we find that the cost of power fluctuates tremendously around the country, by factors of four, five, six, or more. It is fair to say that at the present time the Army is becoming greatly interested in the possibility of a type of what we might call "package power reactor" which can be placed in very isolated communities where there is no hope of any other type of power and where for military reasons it would like to have power. But the cost, of course, would be prohibitive from the standpoint of commercial power.

But from those standpoints, to try to answer Dr. Fermi's question, I think that we can say that the cost of power within the continental limits of the United States varies all over the map. We can get about anything we want to, although it is nothing in comparison to what the Army would be prepared to pay for it in such outlying places as, say, northern Alaska.

MR. GREENEWALT: Then I take it that the answer to Fermi's question in your view would be that, looking at power generation from a strictly commercial and nonmilitary point of view, you do not know of any location, in this country at least, where it would be conceivable that power from atomic energy would be commercially successful?

MR. LOUGHRIDGE: I would not want to make that categorical answer right now, no. I think that Zinn has some ideas on this.

MR. GREENEWALT: I would like very much to hear from him.

MR. ZINN: I would just like to remark that we started out by saying that research uses and so on did not provide any considerable market for atomic power. If we talk about places where power is exceedingly expensive, it cannot be a very large market either. So, how can we interest utility companies and so on in the problem? Utility companies in this country will necessarily be interested in large markets. This means competing with an industry which has had many years of development and has done very wonderful things in making electricity out of coal. This is the basic problem, and it leads to what I call the power dilemma.

We know now how to make nuclear machines which will generate power at a cost which is, let us say, an order of magnitude greater than what is now used or what is the cost in commercial establishments. A submarine reactor is being built. This would have a cost of an order of magnitude or more. We also know how to run very large reactor plants for making plutonium. The problem is to bring these together and get the power out of a large machine at a competitive cost. The dilemma arises because if we try to make the plant small the cost turns out to be large. If we make the plant very large, where we have some chance of getting the cost, let us say, within a factor of two of competitive price, then the capital investment is very large, and the question is: Whose money shall it be? This is the basic dilemma.

MR. GREENEWALT: I think that that is a very fair statement of the problem.

I wonder, then, if we could get down—and now we are getting into the realm of sheer speculation—to what I would like to call the atomic-energy-power problem per se. That is, let us look at the problems which we face in designing and building a power plant the prime product of which will be power and which does not have to rely upon the sale or other disposition of any by-products.

In opening that question, I would call on Joslin and Loughridge to see if we can get some numbers here which indicate how far away in some quantitative way we are from the goal.

As I understand it, Joslin, it is the point of view of the utilities that the atomic-energy installation would replace merely the boiler and the steam which is generated. That is, the electrical generating equipment

and all of that would have to be the same, whether one generated power from atomic energy or from coal. I wonder if you could give us a figure on, let us say, the cost per installed kilowatt of that part of a coal station which would be replaced by an atomic-energy unit.

MR. JOSLIN: The present-day costs run a little different in different parts of the country, but we could assume $170–$200 per kilowatt of installed generating capacity for the total plant, including the fuel-handling and carrying it through, to stepping up the electrical output and putting it in on a transmission grid. Of that possibly $80–$100 would be associated with the boilers and coal-handling which would be displaced by the reactor.

But there is another factor in here about which we had quite a debate in some of our preliminaries this morning. What would be the capitalized value of the fuel? And it is quite a debatable point. But we have to assume, for the moment, that we are burning something else which is just zero fuel cost—namely, the uranium, displacing the coal. Figures will vary all over the map because of the wide range of fuel costs in different parts of the country. But we might say $100–$200 is the capitalized value of the fuel. Adding the $100, the lower figure, to the $80, representing the investment in the portion of the plant displaced by the reactor, we get $180, or we get a range of from $180 to $300 per kilowatt for comparison with the nuclear substitute investment. Is that what you wanted?

MR. GREENEWALT: That is what I wanted. I would like to know also whether anybody would quarrel with those figures substantially?

MR. ZINN: Only in one sense. Let us not get the idea that the fuel costs for a nuclear plant will necessarily be zero. It can be far from zero. It depends upon what kind of plant we build and how we run it.

MR. GREENEWALT: We will come to that. We then can say that the goal for which we are shooting—in other words, what competition has to offer atomic energy—is something that is worth $180, let us say, per installed kilowatt.

Loughridge, I wonder if you could give us a figure which would represent your best present ideas on the cost of an atomic-energy plant per installed kilowatt?

MR. LOUGHRIDGE: One figure which has been released during the last few months is the estimated cost per kilowatt for power generated in

the case of our first nuclear submarine installation. It turns out to be in the order of magnitude of $1,400 per kilowatt in comparison with the $180 figure which has just been quoted. However, I should like to point out that that is a rather unfair competitive comparison, owing to the fact that that figure includes a lot of rather very expensive naval plumbing to stand shocks of one type or another and seems to me not to be a fair figure to use for comparisons. Another figure which I have picked up from the Navy is that the total cost, the fuel and the loading and transportation and all the logistics involved in it to operate a submarine, runs in the order of $1.50 per kilowatt, so you see that the power cost there is terrific.

I think that a fair comparison, if we want to get some figure to compare with the $180 figure per kilowatt, which Joslin has mentioned, would be, with our present technique, probably somewhere in the order of $500–$600 per kilowatt. I think that it cannot compete yet.

MR. GREENEWALT: There we are now. We have a figure of $180 per kilowatt for a present modern coal installation, and we have a figure, which I suppose is at best a very high spot guess, of $500–$600 for an atomic-energy installation which could be made today. So that one can see at a glance that the gap is a rather wide one.

It is time now to deal with another $64 question, and that is this assumption that the cost of the fuel in an atomic-energy installation is zero. I think that I know what Zinn has in mind in questioning that that may be so. That, I think, brings in this question of breeding. Is that right, Zinn? Could we put it this way: That the assumption that the fuel will cost a negligible amount in an atomic-energy plant is dependent upon our ability to design a reactor which will breed? Because, obviously, if one could use only seven parts per thousand of the charged material, the fuel cost can scarcely be negligible and may be very substantial. So that the assumption that the fuel will cost nothing is dependent upon the solution of the breeding problem. Now I know that Zinn has been very much interested in solving the breeding unit, and I would like him to speak for a moment, if he will, upon the feasibility of designing a unit that will breed in fact.

MR. ZINN: It should be realized that if we burn up 100 atoms of uranium 235 and replace it, let us say by 80 atoms of uranium or plutonium, and then burn those 80 atoms of plutonium, and then replace those by some other plutonium atoms, and so on, we have extended

very considerably the 0.7 per cent of uranium 235 available. This regeneration of fuel and burning it in the reactor are the things which give us the possibility of getting the fuel costs low. We call it "breeding" when it actually turns out to produce more atoms of the plutonium than atoms of uranium 235 burned, but this is just an imaginary boundary line and is not necessarily the crucial point. I believe that reactors which can do this—namely, replace some of the uranium 235 by plutonium and then burn the plutonium—are practical today and that such reactors are the ones which ought to be built as the first ones, in an attempt to make economical central station power. If we do not take this line, but rather say that we will put off attempting to get some regeneration, then we will not ultimately have much chance of competing with coal as a fuel for power plants.

MR. THOMAS: I take an exception to that. I have been waiting for this.

MR. GREENEWALT: I was hoping that we would get a little controversy.

MR. THOMAS: I have no quarrel with Zinn or anybody on breeders or such things. I think that it is splendid, but I do not have to call to your attention, Greenewalt, this word "monopoly," I assure you.

MR. GREENEWALT: Oh, gee!

MR. THOMAS: Some of us are fearful of monopoly in government as we are in other places; and the paradoxical thing is that the Atomic Energy Commission is just as afraid of it and would like to break this monopoly in the future. The way to stop a monopoly and the way to get started on this thing is to get moving. I would certainly underline Zinn's ideas, but I think that the way to start it, as my good friend Joslin has said, is to start out with the Model T Ford, because I think that many plants will have to be built before we get to the ultimate. Therefore, I advocated, two years ago, this dual-purpose plant.

It seems to me strange to worry about the usefulness of plutonium when the Atomic Energy Commission has not broken ground on additional plants to produce more plutonium. Therefore, I would think that a combination plant, where by making plutonium and selling it to the government at a price no more than it is costing the government, using the same bookkeeping methods in both processes, over a period of five to seven years, would be a sound way to get started to make power economically, which we feel we can do at present times, carrying a dual-purpose plant.

As Zinn points out, quite correctly, this is largely a plutonium plant. So what? We certainly need plutonium, or we would not be building more additional plutonium plants today. But, by making this combination, in the interim period—in the next ten years—to get started, to throw this thing open to industry, we feel is important. The fact that there is disagreement between Zinn and me is a great compliment to the fact that he believes in competition. If anybody wishes to have a plant going one way, and we wish to have a plant going the other way, we think that it is in practice with the American industry to let them go their respective ways and not have a governing body set up which is going to appoint additional committees to study this plan and that plan and then pass judgment on which one is correct. Let us throw it open; and if we fall on our face, let us fall on our face; and if Zinn falls on his face, let him fall on his face. But let us just get this thing open to competition.

MR. GREENEWALT: There we are, gentlemen, completely unrehearsed. I take it, however, Thomas, that you would still feel that this so-called "dual-purpose plant" is no more than a step—but in your view a very necessary step—on the way to what I have called an atomic-power plant per se?

MR. THOMAS: That is correct. But it is an essential step, because it is time to get started on this thing. Probably after we have got this plant built, we would have something which was obsolete. Greenewalt and I both know that in the chemical industry this is usually the case. We build plants which are practically not finished before they are obsolete, and that is something with which we have to contend. Now, Zinn, what are you going to say?

MR. ZINN: Just this: I have seen two plants in their design and construction phase, whose purpose it is to make plutonium, and I think that I know a great deal about how they were designed and how they are to be operated. I have also seen an experimental plant which makes electricity in its design stage and operation. And I have had close connections with a plant which will operate a submarine. So, I know something about a plant which will make power.

I am getting a little impatient, however, in looking at plants which always make something else. They make plutonium, or they make military power; but they are not directed toward making civilian power and making it economically. I am fearful that, so long as we keep our

eyes on making something else, the thing which we really want will not come about. And there is a real danger here, because the things which are something else have a very high price; and this very high price does not encourage in the designers and the builders and the operators the greatest care in getting down the capital costs of the plant. It is this high capital cost which leads to the $500 or $600 figure which Loughridge mentioned. I have, of course, every hope that competition will do this; but we need to have, therefore, more than one such plant under construction and not a guaranteed price of plutonium from the government but a competitive price for plutonium or the military use in order to get the cost down. The guaranteed price from the government can hardly be called competition, because you are competing with plants which were built under entirely different arrangements, and it was not to get the cost of the power down.

MR. THOMAS: If this is unrehearsed, let it be unrehearsed. There is a counterproposal, which I think you indorse, government-subsidized power—that is, this package power plant. Dr. Fermi spoke of places where the small power plant would be possible, and he fell right back into the argument that the military would need it. In this dual-purpose plant, unless the plutonium could stand on its own feet competitively with what the government could make plutonium for, it would not have my indorsement.

There is such a thing as amortization, and the thing of which I am speaking is that if the high capital cost of a nuclear reactor, at the dual-purpose plant selling plutonium competitive at the present costs of the government, gives us an opportunity, over five years, to write that capital off, then we have an entirely different picture. And then we have our capital costs reduced, because any of us who have fooled with this—and I am not doubting your great knowledge in it, I assure you—realize that the capital costs are the big cost items in the cost of power of atomic-power plants.

MR. ZINN: But is not the difficulty that perhaps the only plutonium plant which the government really has now under your basis of five years is already amortized? It is rather tough to compete with it.

MR. THOMAS: I do not think so, because we are building some more at Savannah River, for example. Loughridge can tell us more of that if he can—I do not know; it may be top secret.

It is the future power plants, not that we have at Washington, which

were built in wartime, of which we are speaking. We are talking about the plutonium plants which are not in production yet but which are now under construction.

MR. WALLIS: I was going to ask Zinn what he would think of simply having the government call for competitive bids to supply plutonium.

MR. ZINN: I do not think that you would get any bids!

MR. THOMAS: Zinn, that is where I differ with you.

MR. GREENEWALT: What about another problem? Is there adequate uranium for atomic-power plants?

MR. DAVIDSON: Recently the Commission asked Dr. Palmer Putnam to look into this very matter, and he concluded that if we do admit the possibility of utilizing all the uranium in the earth's surface—all the economically recoverable uranium, that is—there is several times as much heat energy in the uranium that can be economically mined as there is in the coal which can be economically mined from the earth. So, on that basis, I think that we can conclude that we do have sufficient nuclear fuel available if we can only find an economic way to put it to use.

MR. GREENEWALT: I would like to close by asking a real crystal-ball question. I think that we have developed today that there is still a substantial distance to be gone before we can have an economic competitive atomic-energy power-generating unit. We have heard considerable discussion about various methods of arriving at that goal. I would like the panel really to look into their crystal balls and to say when that goal will be reached—whether it will be ten years, twenty years, fifty years, or never? Let us go around the table.

MR. LOUGHRIDGE: I will cast fifteen years.

MR. GREENEWALT: Fifteen years before we have an economic unit.

MR. DAVIDSON: I have noted in asking this question and hearing it kicked around that the optimists are those people who have never built a reactor. I have never built a reactor, and so I will say that within ten years I think that we will be able to demonstrate that power can be made competitive from nuclear fuel.

MR. WALLIS: I have absolutely no technical competence in the field, so before the meeting I looked up the history on similar predictions on other inventions which have been made in the past; and my prediction

is that none of the predictions made here, or elsewhere, will bear any relation at all to what is going to happen.

MR. GREENEWALT: That is probably the wisest answer of all.

MR. FERMI: Subject to full agreement with Wallis' conclusions, my impression is that twenty years may be a reasonable figure.

MR. COMPTON: I already gave, earlier today, some crystal-ball-gazing, and I think that I would stay by it. I would be surprised if we do not have some actual commercial applications of atomic power within ten years. Those will be in the more expensive power areas. In large-scale production of power on an economic basis, my guess would be closer to fifty years.

MR. ZINN: It depends a great deal upon when we set up in our mind to do it. We have not heard here today anything about the infeasibility of doing it. We have not had any hint that we need some new technical approach in order to make it possible. Therefore, what is needed is decision and determination to give it a whirl, and I believe that it may take three or four or five years to make up our minds to build a large-scale plant specifically for making power. When we do this, after another three or four years for construction, we will have it.

MR. GREENEWALT: That adds up to ten years, approximately.

MR. JOSLIN: Again from the sandlotter. It can be, I believe, within ten years—talking economic power again—but is not likely to be, at the rate that it is moving.

MR. THOMAS: I find myself in complete agreement with Zinn and what he just said. I would rather not comment on this question, because I think that it is completely irrelevant. This question has been posed at every panel which we have ever had on this subject, and I think that it ought to be outlawed.

What is important is first to get the law changed. We cannot have any commercial power with the atomic law as it now exists, in my opinion. It does not have to be changed radically, but there have to be some changes in detail in the law. I agree so fully with Zinn and with Wallis that the important thing is to get moving and get started and not worry about when we are going to do it, because that is the question which I think is so burning before the American public and the world today. So, I have no comment to predict when it will be. I am only urging that we get started.

THE PROSPECTS FOR INDUSTRY*

By EDWIN J. PUTZELL, JR.
Secretary, Monsanto Chemical Company

*

In September, 1946, Charles Allen Thomas, now Monsanto's president, told the American Chemical Society of a survey that he and others had just completed for the United Nations Atomic Energy Commission. This study showed that electricity from a nuclear plant could be produced for little more than the cost of producing power from coal-fired generating plants.

In 1950, Dr. Thomas outlined a plan for a plant, producing both power and plutonium, constructed and operated by industry with its own funds. The power would be used or sold by the producing company; the plutonium would be sold to the government at a price that Dr. Thomas believed would be lower than it would cost the government to make plutonium in its own plants.

In mid-1951, the Commission contracted with four industrial groups—one of them a team from Union Electric Company of Missouri and Monsanto—which, at the team's own expense, would investigate the technical and economic feasibility of producing electric power from nuclear energy.

Some have wondered about a chemical company's role in the development of atomic power. There are three major reasons why Monsanto is interested and anxious to participate in the program:

First, the operation of nuclear reactors is essentially one of chemical engineering.

Second, Monsanto uses tremendous quantities of electric power. Last year, our electric power bill for manufacturing operations in the United States alone was over $7,000,000.

Third—and perhaps most important of all—we feel we could produce plutonium at a lower cost to the government than it is produced now. This implies no criticism of the Atomic Energy Commission or of its contractors. We believe the AEC has done—and is doing—a remarkably efficient job.

* This and the following article are reprinted by special permission of the *Bulletin of Atomic Scientists* (November, 1952), from its panel on "Private Industry and Atomic Power."

But there is no gainsaying the fact that savings accrue from the techniques and methods of the free-enterprise system. The profit incentives alone give it a definite edge over governmental operation, no matter how efficient the latter may be.

A year ago, when we approached this study of the feasibility of a combined plutonium and power producing reactor, there were three kinds of questions—technical, economic, and legislative—that had to be answered.

Monsanto and Union Electric now have been able to give the AEC an only slightly qualified "yes" in answer to the question, "Is such a project technically and economically feasible?" Recently, we reported to the Commission that the investigatory phase is virtually completed; that, in our opinion, now is the time to start the design and then the construction of a pilot plant.

I do not want to misrepresent our position: In terms of full-scale producing units, nuclear-generated electric power is still perhaps four or five years away. But we are ready to commence preliminary work toward a pilot plant.

Under the direction of Drs. Philip N. Powers and C. Rogers McCullough, the Monsanto–Union Electric team reviewed all the suggested approaches to producing electric power from atomic energy. They concluded that there is no *present* possibility of constructing a reactor that would produce power only. The manufacture of plutonium as a co-product of the reactor is necessary at present.

Using the Hanford reactors as a starting point—because more is known of this type than of any other—our team concentrated on changes which were indicated. They concluded that a moderated reactor[1] shows promise as a plutonium and power producer. Similar conclusions were reached by an engineering organization which also has been studying the problem.

Our team is not satisfied that this is the only type of power-producing reactor feasible. They also want to find a type which will produce power alone, without plutonium, and will continue to work toward that end; but it appears that a decade or more of intense research and development lies ahead before such a reactor could become a reality.

As a result of their feasibility studies, Monsanto and Union Electric have proposed that the AEC embark upon the design of a pilot plant reactor as soon as possible. We believe that the government should construct and own this plant, until it is decided whether the present law prohibits private own-

[1] I.e., a slow-neutron reactor, containing a moderator such as graphite, in contrast to non-moderated "fast-neutron" reactors.

ership of facilities producing fissionable materials in the amounts which such a pilot plant would make. In the interest of time-saving, and of the efficient use of presently existing facilities and experienced technical manpower, the pilot plant should go forward promptly, under government auspices and with government funds. For our part, we propose to have a full share of responsibility in the design, construction, and operation of this plant, and want to cooperate with the Commission at every step in this program.

We believe that once the pilot plant is completed, and the remaining technical questions answered, private industry will invest its own funds in the construction and operation of a full-scale plant for the production of power and fissionable materials. However, to reach that end, a few changes may have to be made in the Atomic Energy Act.

While we will be working with the Commission in the construction of the pilot plant, Monsanto and Union Electric would continue the study of other types of reactors. During the last year, we invested a considerable sum in this work; an even larger amount will be spent during the coming year. We have assembled a highly qualified staff of scientists and technologists from our own companies, have hired qualified men to supplement them, have contracted with universities for special studies to be conducted, and generally have availed ourselves of the technology that government research has produced and which the Commission has willingly made available to us and to other industrial study teams.

In the next phase, during pilot plant design and construction and continued longer-range reactor research, a new type of industry-government cooperation will emerge. The government and industry would both be investing money and personnel in pushing forward the atomic power development.

Security and safety regulations concerning personnel and property, would continue to be the primary responsibility of the AEC, as is required by the Atomic Energy Act. At the outset, we realized that paramount security and safety requirements were to remain where the Congress has put them, and we have planned our future operations with that in mind.

In studying the feasibility of the industrial development of atomic power, we have borne in mind that the project will have to compete for capital with other investments open to a businessman. The risk of investing in atomic power development must not be much greater than the normal business risk. That means that the power-plutonium reactor must have a reasonable assurance of a market for its products, at fair prices, for a period

long enough to permit the investor to obtain a return of his funds. In normal commercial operations, there may be tens, or hundreds, or thousands of customers; but in the case of plutonium, the government is the sole purchaser. The loss of this customer could have disastrous results.

We plan to explore with the Commission the type and duration of an agreement under which private industry would construct and operate a plutonium-power reactor and would sell plutonium to the government at stated prices.

Another new problem—to which some answers may be obtained from the pilot plant operations—is that of the life span of a plutonium-power reactor. The price of the plant's products will have to be influenced by the rate of its depreciation.

No atomic power development program can hope to succeed without continuing access to the government-owned reactor information and technology. Ever since the creation of the Manhattan District, the government has been—properly so—the exclusive repository of all important technical information in this field. In this connection, let me say that the AEC has been most cooperative in supplying our security-cleared team with the necessary information. This same cooperation, we are sure, will continue as the power program progresses, and will be maintained also in the final stage, when the government will begin purchasing plutonium from the private processor.

While no firm commitment has been made by the AEC that it will design a pilot plant reactor of the recommended type, we are most encouraged by the Commission's reaction to our proposals.

As mentioned earlier, some of the problems to be overcome lie in the legislative or legal sphere. One is the scope of the prohibition, written into the Atomic Energy Act of 1946, of private ownership of facilities for the production of fissionable materials. In the preamble to the law, Congress declared the policy of the United States to be aimed at the development and utilization of atomic energy for strengthening free competition in private enterprise, subject only to the paramount object of assuring the common defense and security of the nation. No threat to national security needs to result from private ownership of facilities to produce plutonium and electric power, under security safeguards maintained by the government. Adequate machinery can and should be found to police these private plants.

In proposing world control of atomic energy before the United Nations Organization, Mr. Baruch asked for a commitment that there be free and frequent inspection of all participating nations and their work in this field.

If such inspection is workable on a world-wide basis, it assuredly can work with private industry in this country.

Another problem is the need to protect inventions and original ideas developed in the course of the plutonium-power program. Admittedly, patents and inventions dealing solely with the utilization of atomic energy for military purposes should remain the property of the government. However, to give maximum encouragement to industrial development of atomic power reactors, there should be a modification in the present policy which forbids the granting of patents for any invention or discovery useful solely in the production or utilization of fissionable material. While it is understandable that such a rule was adopted when almost all inventions were obtained at the government's expense, with the approaching possibility of major industrial programs in the field of atomic power, a review of such policy is in order. For example, should not some protection be granted to a company which has, at its own expense and effort, found ways to apply atomic reactors as tools in the chemical manufacturing industry?

Let me comment briefly on the great potential that lies in the production of nuclear-created electric power as a tool of diplomacy in opposing the aggression of totalitarian powers. The atomic power project, while it can be useful in our own country, could be even more helpful in developing the resources—and the defenses—of other free nations of the world, once the enabling legislation is adopted.

Look at England. It is now almost too costly for her to produce electric power from coal mined within her boundaries. At Ruabon, North Wales, Monsanto has a chemical plant, and immediately adjacent to it is a government-owned coal mine. Some of the shafts of that mine are beneath our plant. However, on many occasions since the war, that plant has had to purchase coal in the United States and ship it to England. It was cheaper to purchase the coal in New York, ship it to London and transship it to Ruabon than to purchase the coal from the mine next door. How great, then, must be the range of possible benefits to the British economy, of power produced from atomic energy.

Last week, the Italian consul in St. Louis came to tell me good-by, as he was returning to Rome. The conversation soon got to Italy's present economic and social conditions. The consul stated that in his judgment, most of Italy's problems stem from lack of cheap fuel for the production of capital goods. His country has no coal or oil of its own; the maximum possible utilization of water is in sight, and there is only a limited supply of natural gas in a recently discovered field. In his opinion, the only new possibil-

ity in sight is power from atomic energy. It alone has the potential for lifting the Italian industrial economy, and raising the living standards of 48 million people.

Similar possibilities exist in other areas, such as South America, Australia, and Africa. Abundant natural resources lie dormant in many instances because the lack of cheap electric power makes them inaccessible. Many arid regions could be made productive if power were provided to pump the needed water.

There has been much talk of the Point Four Program, which would make American technological advances, and engineering and economic know-how available to other areas of the free world. In the development of nuclear-produced electric power we have the greatest tool for contributing to the economic and social development of other nations. Under controls, such as those outlined in the United Nations atomic control plan, an "Atomic Power Plant—Point Four Program" could result in greater advantages, psychologically and materially, than any other weapon in the struggle against aggression.

Based on a speech given at the Fifth Annual Summer Institute of Atomic Energy, University of Michigan Law School, on June 26, 1952.

POLICY PROBLEMS IN THE DEVELOPMENT OF CIVILIAN NUCLEAR POWER

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The emphasis in the atomic energy program has been on applications for national security with the consequent subordination of civilian uses such as power. Another factor, which has seemed to lessen the emphasis on the power field, is our country's comparatively bountiful supply of low-cost conventional fuels.

But now, even in the six months I have been with the Commission, there is a noticeable quickening of interest in atomic power.

I am not one to name a date, but I will say that we will have one, or perhaps a few, nuclear power plants producing electricity for industry or central station networks sooner than the ten or fifteen-year period we were estimating a short while ago.

There are some who urge that all the United States needs to do is to change the Atomic Energy Act so that the restrictions on the private ownership of reactors and the private acquisition of patent rights are lifed. Then, the argument runs, industry will really go to town.

Because the Commission is in the process of considering this problem, I am not prepared to give detailed answers. I will state, however, that this seems to me an oversimplification.

I would like to mention some of the questions that seem to demand deep and farsighted consideration.

The first and foremost question is: How do we tie in civilian power with national defense? The requirement of national defense is the first consideration at the Commission. It is the reason for the extensive development of atomic energy today. Had there been no World War II, no need for advanced weapons, the progress made during the last ten years might have been achieved only in small measure.

Does the development of atomic power collide with, or is it consistent with the nation's needs for the common defense and security in the broadest sense? This is a question with many facets. For example: Will developing civilian atomic power divert more fissionable material than prudent from military uses, that is, from use as bombs and as submarine and aircraft fuel? And: Can an atomic plant be built to contribute to both civilian and military objectives?

At the present time we are thinking of atomic power as co-product of plutonium, both coming from atomic reactions taking place in uranium, converting part of it to plutonium, and releasing heat which could be used in generating electric power. If atomic power is to be provided as a co-product, by dual-purpose reactors, the role of the government in buying the plutonium produced will have much to do with success in turning out power at a reasonable cost. Unless the government buys plutonium at prices equivalent to its own production costs, at this stage of development, the cost of generating power might be so prohibitive that no commercial firm would undertake it.

Whether or not industry can undertake a greater role in power development, as a by-product of plutonium manufacture, might depend on the assurance of a guaranteed market for plutonium during the next ten, fifteen, or twenty years. Before private investment could be attracted to this field, assurance—based on sound contracts—would have to be furnished that the government would continue to need plutonium.

Such a long-range buying plan should also consider the interest of the

taxpayer and fairness to all companies concerned. If the military and civilian uses of plutonium enable us to give only a limited guarantee for a period of years, the question would arise of whether we would be justified in buying plutonium for stockpiling beyond the needs, foreseeable at the time. Otherwise, the number of participants in the program might have to be sharply limited, presenting the problem of how to select companies which would be allowed into the circle.

The problem of purchasing plutonium carries along a companion problem—that of pricing. The price formula should provide a profit incentive covering the entire operation, that is, it should take into account both the plutonium and the power sold, as a package on which the seller could make a profit. But how would the price be worked out to assure adequate incentive without entailing unjustified subsidy of atomic power? Can a system of competition among interested companies be fashioned to strike the appropriate balance of these factors?

There is another possibility. If the day should come, which all of us—no matter how doubting we might be—fervently hope will come, when world peace is a reality, when international control of atomic weapons succeeds, or, at last, when international conditions are more tranquil than they are today, would there be a need for the government to continue buying plutonium?

If the buying of plutonium were stopped, it is easy to imagine the dislocation to civilian industries that would have sprung up around reactor sites to utilize atomic power. With a sudden stop order on plutonium buying, and the resultant sharp increase in the cost of power, what means could be devised to avoid or minimize dislocations?

It may be that such problems as these I have been talking about concerning plutonium will never have to be solved. We may hit upon the development of power at competitive cost from non-plutonium producing reactors, though now it appears that this day is not quite at hand. The first step may be non-plutonium producing power reactors for remote, power-starved areas. Study of the development of atomic energy from 1942 leads me to feel that the strides the engineers and scientists are making are so great that "power only" reactors may be nearer than we dare hope for, even though we are still in the early phases of research and development.

Regardless of the type of reactor that furnishes the power, we will still need answers to a number of other questions.

One of them concerns the location of plants.

We are sometimes thought to be too conservative in locating plants be

cause we will not extrapolate on the basis of experiments. I can only say that extrapolation, when hundreds and even thousands of lives may be involved, seems to us a slim reed to lean upon.

It is easy to see how the location of the reactors can influence the cost and availability of atomic power. The problem is to determine the responsibility of the government for establishing criteria governing the locating of privately-operated nuclear power plants, and determine the methods of executing these responsibilities.

Another question is: What should be the government's responsibility for health and safety within privately-operated atomic plants? The Atomic Energy Commission goes to great effort and expense to protect those who work in the industry. Would private industry be able to devote as much attention to these problems?

The problem of security is always with us, and will be of particular concern when the power reactor also produces plutonium.

Undoubtedly, reactors for producing atomic power will incorporate the latest and best technology. Therefore, these reactors will be prize targets for espionage and sabotage by unfriendly nations. What arrangements could be established to assure adequate protection of private atomic plants in the interest of the national security?

The government takes special care to assure continuity of operations in its atomic plants. What provisions can be adopted to assure such continuity in the private plants? For example, would a special labor-management undertaking be needed?

What provisions can be made to assure that only loyal and reliable employees have access to secret work in private industry's atomic plants? We would not expect the FBI, for example, to turn over its reports to private corporations. How are we to handle the problem of the determination of individuals as good security risks? Such problems of security, so closely related to national defense, clearly call for the careful spelling-out of a partnership between industry and the government.

One big problem, with its several corollary problems, remains to be mentioned. It relates to the stake of the taxpayer in atomic energy.

With almost ten billion dollars of their money, the American people have built up a gigantic publicly-owned industry. At the present time these taxpayers, through their Defense Department, are also the biggest customers of this industry. When we consider the coming of civilian nuclear power, what are the rights of the people (the taxpayers) as original stockholders, and

what are the rights of private enterprise, upon which our whole economy is built?

How are incentives to be provided for private industry, with full recognition of the stake of the taxpayers in the atomic energy activities they have sponsored?

Of course, amendment of the present restrictions on private ownership of reactor facilities and the establishment of equitable patent arrangements are inevitable if private enterprise is to be attracted.

In other words, patent and property provisions must be drawn in such a way that there can be a profit, a competitively attractive profit. In the same pattern, there must be engineering competition between private companies so that industry will make maximum contribution to nuclear power development. It is this competition which will most effectively drive down costs and bring technological advance.

Yet, we must not forget that the atomic energy industry is unique in the history of our industries. Every step—research, development, and production—has been paid for with taxpayers' money; every cent of the cost of the vast capital structure underlying atomic energy has come from the same source.

There can be no doubt of the stake of the taxpayer in patents developed as the result of cost-reimbursement-type contracts at government expense. The question that arises is: At what stage in the cooperative development of atomic power does the private company begin to acquire rights? How do we insure equitable access to the know-how, developed at government expense, which must be the background for many patent developments?

The atomic energy research is so expensive that it is inconceivable that industry could support the research program necessary to achieve continuing progress in the shortest possible time. In view of the inextricable relationship between national security and atomic energy, we must ask: Has government a continuing obligation to assure that broad research activities in the nuclear field are continued at a satisfactory level?

Finally, this new source of energy is one of our great natural resources. As the custodian, the government has a special responsibility, in the words of the Atomic Energy Act, for "the development and utilization of atomic energy toward improving public welfare, and increasing the standard of living." What mechanics are needed to insure that the government will be sufficiently knowledgeable and capable to carry out that responsibility?

Portions of an address before the Chicago Section of the American Chemical Society, September 11, 1952.